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THEORETICAL AERODYNAMICS RESEARCH LABORATORY/ARL

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A series of cavity shapes was tested on the sidewall of a Mach 3 high Reynolds number wind tunnel to determine the effects of the cavity and its downstream lip shape on the external flow. Various mass injection rates into the cavity were provided. Holographic interferommetry, oil flow, and a fast response surface pressure transducer were used to take data.

Results indicate that a rectangular cavity with a lip shaped as a short rounded overhang least disturbs the turbulent boundary layer. Low levels of mass injection were found to have little effect on boundary layer quality.

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PREFACE

This report was prepared by Dr. James S. Petty, Capt James R. Cooper and Dr. Robert H. Korkegi of the Theoretical Aerodynamics Research Laboratories, Air Force Systems Command, United States Air Force, under Project 7064, entitled "High Velocity Fluid Mechanics."

The reported wind tunnel tests were performed in ARL's 3" x 3" Mach number 3 wind tunnel.

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SECTION I

INTRODUCTION

Cutouts such as the mirror cavity and the one for the interstage duct in gas dynamic lasers such as the SSD (Fig 1) can cause nonuniformity and extensive thickening of the sidewall turbulent boundary layer.

The quality of the sidewall boundary layer is a key factor in the performance of the laser diffuser in which the flow must be recompressed effectively to exhaust to the atmosphere. It is particularly important as the sidewall boundary layer is subjected to three-dimensional shock wave interactions which cause separation and flow deterioration at much lower pressure ratios than for two-dimensional shock wave interactions (ref 1). Thus the sidewall interaction is the limiting factor in diffuser performance.

If the sidewall boundary layer is highly nonuniform and very thick, diffuser performance will be further limited.

It is the purpose of this report to present results of a study of various cavity configurations and to recommend a design which least disturbs the sidewall boundary layer and should therefore help to improve diffuser performance.

SECTION II

CAVITY SHAPE STUDIES

Configurations investigated on the wall of a 3" x 3" Mach number 3 wind tunnel at ARL are a circular cavity (Fig 2a), a rectangular (essentially two-dimensional) cavity (Fig 2b), and four different downstream lip shapes for these cavities, including a square lip (Fig 3a), a lip with a short, circular overhang (Fig 3b), a lip with a long overhang (Fig 3c), and a rounded shoulder (Fig 3d).

Blowing was also investigated in order to simulate the effect of nitrogen injection used to avoid thermal blooming in the interstage duct.

In all cases the cavity length was approximately ten times the thickness of the oncoming turbulent boundary layer. Equivalent Reynolds numbers were of the order of 10^7.

1. CIRCULAR CAVITY

According to oil flows and interferograms the flow of a turbulent boundary layer across a circular cavity (Fig 2a) is highly nonuniform span-wise (three-dimensional) and results in the thickening of the boundary layer irrespectively of the type of lip used. An oil flow pattern tunnel and cavity wall is given in Fig 4.

2. RECTANGULAR CAVITY

In all cases, the flow over a rectangular cavity extending from wall to wall in the wind tunnel (Fig 2b) was nearly uniform (two-dimensional) as shown in oil flow of Fig 5.

A rectangular cavity with a square lip (Fig 3a) and the rounded shoulder (Fig 3d) both resulted in a strong disturbance including a shock and separation bubble at reattachment, as illustrated in Fig 6a and shown in the interferograms of Fig 7. This configuration produces a thick turbulent boundary layer on the diffuser sidewall, prone to early and extensive separation.

A rectangular cavity with a long, rounded overhang (Fig 3c) resulted in instability and oscillation of the separated boundary layer with expected poor diffuser performance.

The rectangular cavity with a short rounded overhang (Fig 3b) gave the cleanest reattachment with minimal disturbance as illustrated in Fig 6b, and shown in the interferogram of Fig 8. This configuration is expected to least degrade diffuser performance.

3. EFFECT OF BLOWING

Tests were made with air injected nearly uniformly across the floor of the cavity in order to simulate blowing to avoid thermal blooming in the interstage duct. The mass flows injected were varied up to approximately

5% of the boundary layer mass flow across the cavity. For rates up to 1%, the mass injected had little effect on the cavity flow. At a rate of 5%, there is significant degradation as indicated in Fig 9 by the shocks and boundary layer lift off downstream of the cavity. It is expected that rates of 20% will cause the boundary layer to lift off the surface so that the lip shape becomes totally ineffective.

SECTION III

CONCLUSIONS

Of the circular and rectangular cavities with various lip configurations, a rectangular cavity with a lip shaped as a short, rounded overhang least disturbs the turbulent boundary layer and is therefore recommended for consideration for the various sidewall cavities (mirror, interstage duct) in gas dynamic lasers. Blowing rates up to 1% of the boundary layer mass flow show little effect on boundary layer quality.

Although the experiments described are for a turbulent boundary layer and only one Reynolds number, other experiments with laminar boundary layers over cavities show qualitatively the same behavior (ref 2).

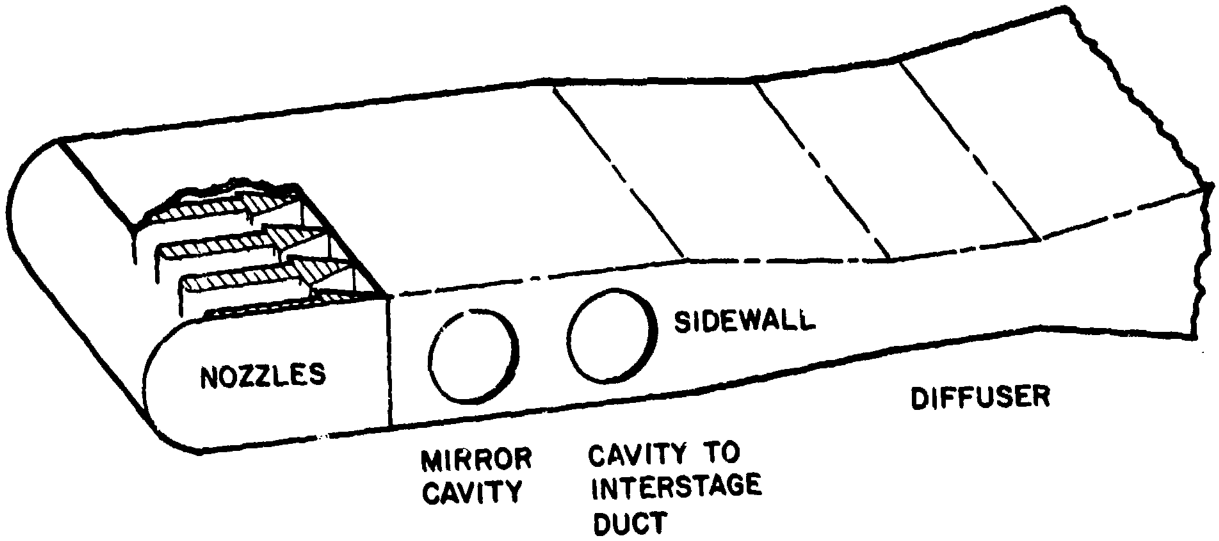
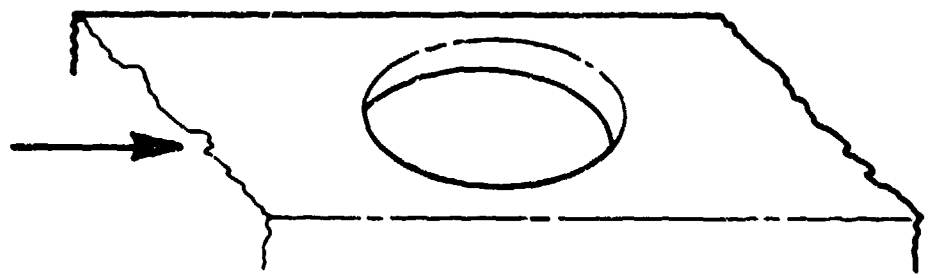
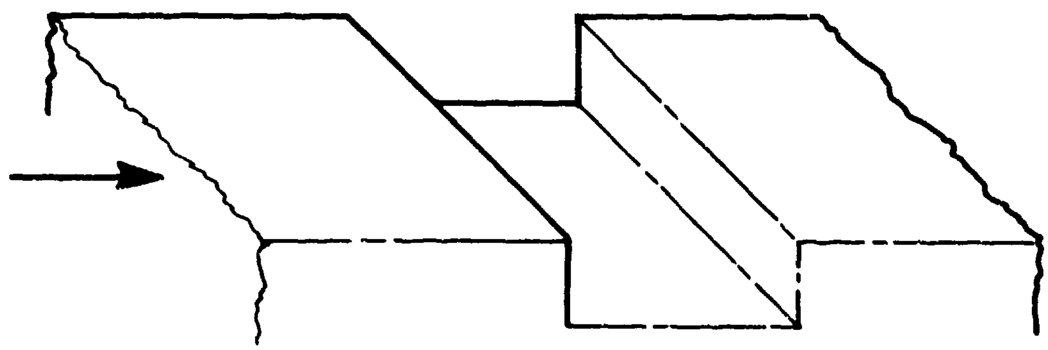


Figure 1 GAS DYNAMIC LASER (SSD)

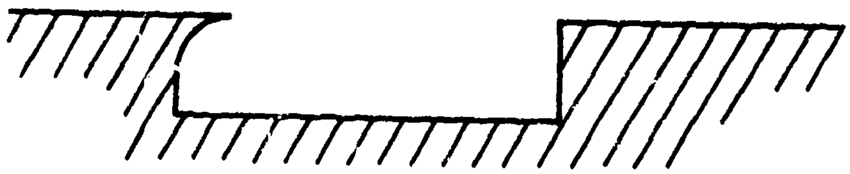


a. Circular

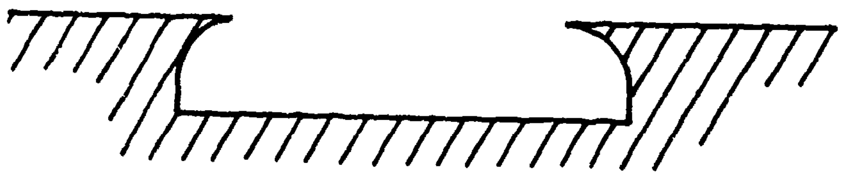


b. Rectangular

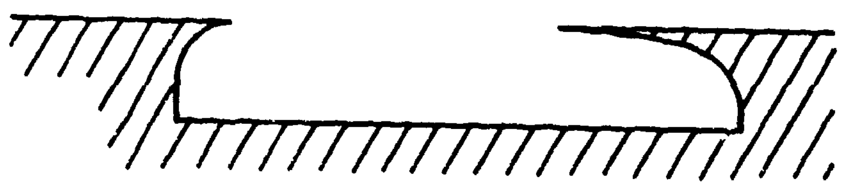
Figure 2 CAVITY SHAPES



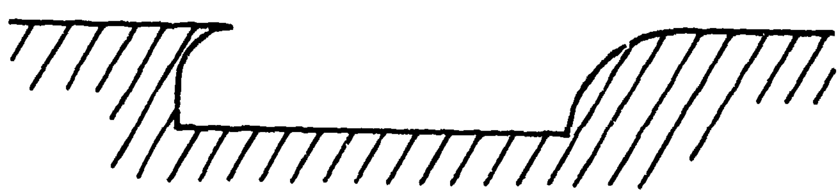
a. Square



b. Short rounded overhang



c. Long rounded overhang



d. Round shoulder

Figure 3 DOWNSTREAM LIP SHAPES

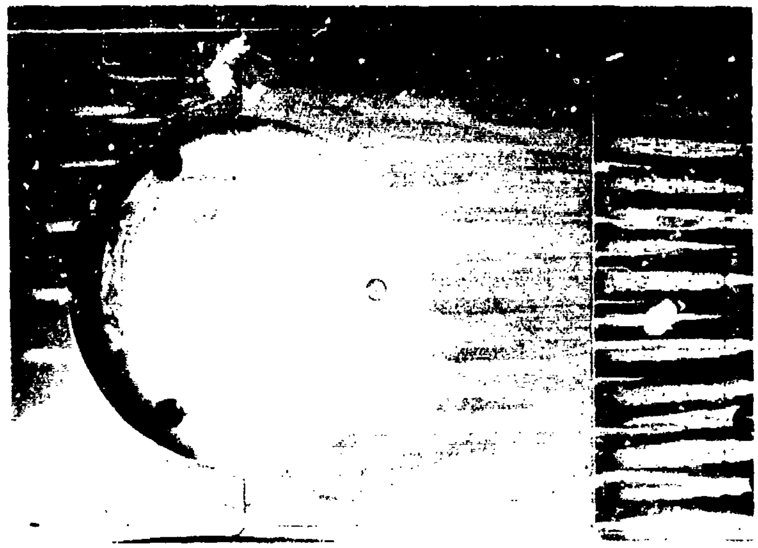


Figure 4 OIL FLOW PATTERN NEAR CIRCULAR CAVITY

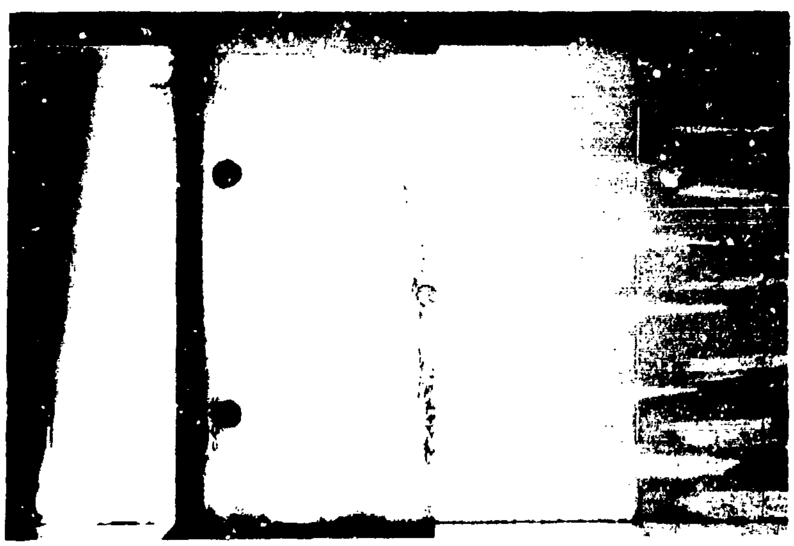
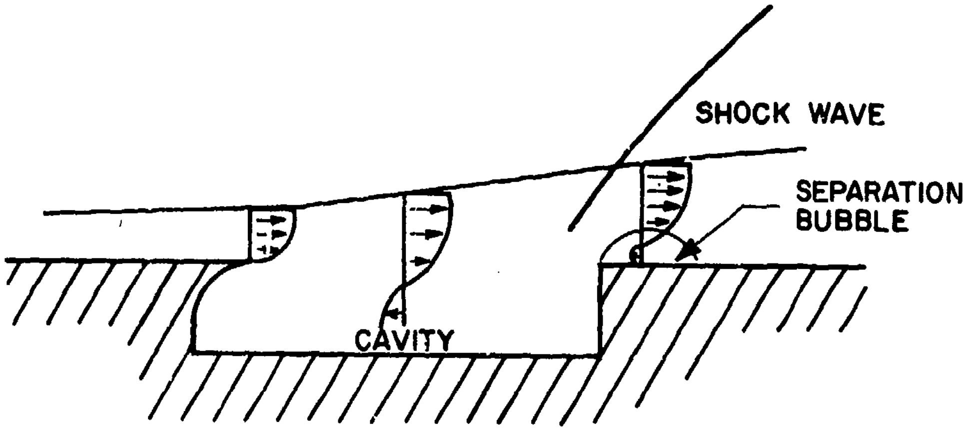
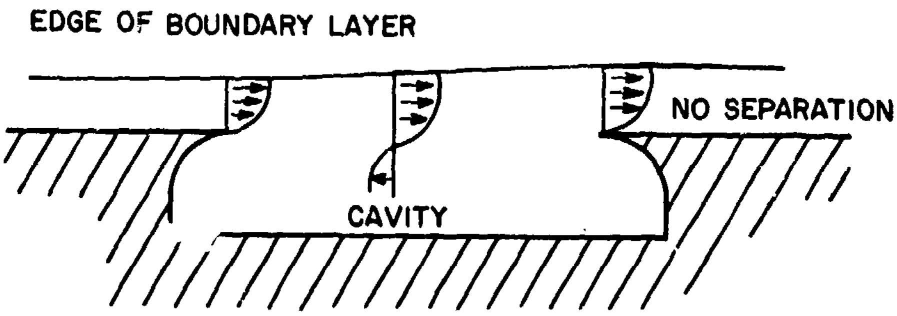


Figure 5 OIL FLOW PATTERN NEAR RECTANGULAR CAVITY



a. Strong disturbance at reattachment and thick boundary layer



b. Weak or minimal disturbance at reattachment

Figure 6 TYPES OF DOWNSTREAM CONDITIONS

Figure 7 INTEROFEROGRAMS OF FLOW OVER CAVITIES WITH DIFFERENT REATTACHMENT LIP SHAPES

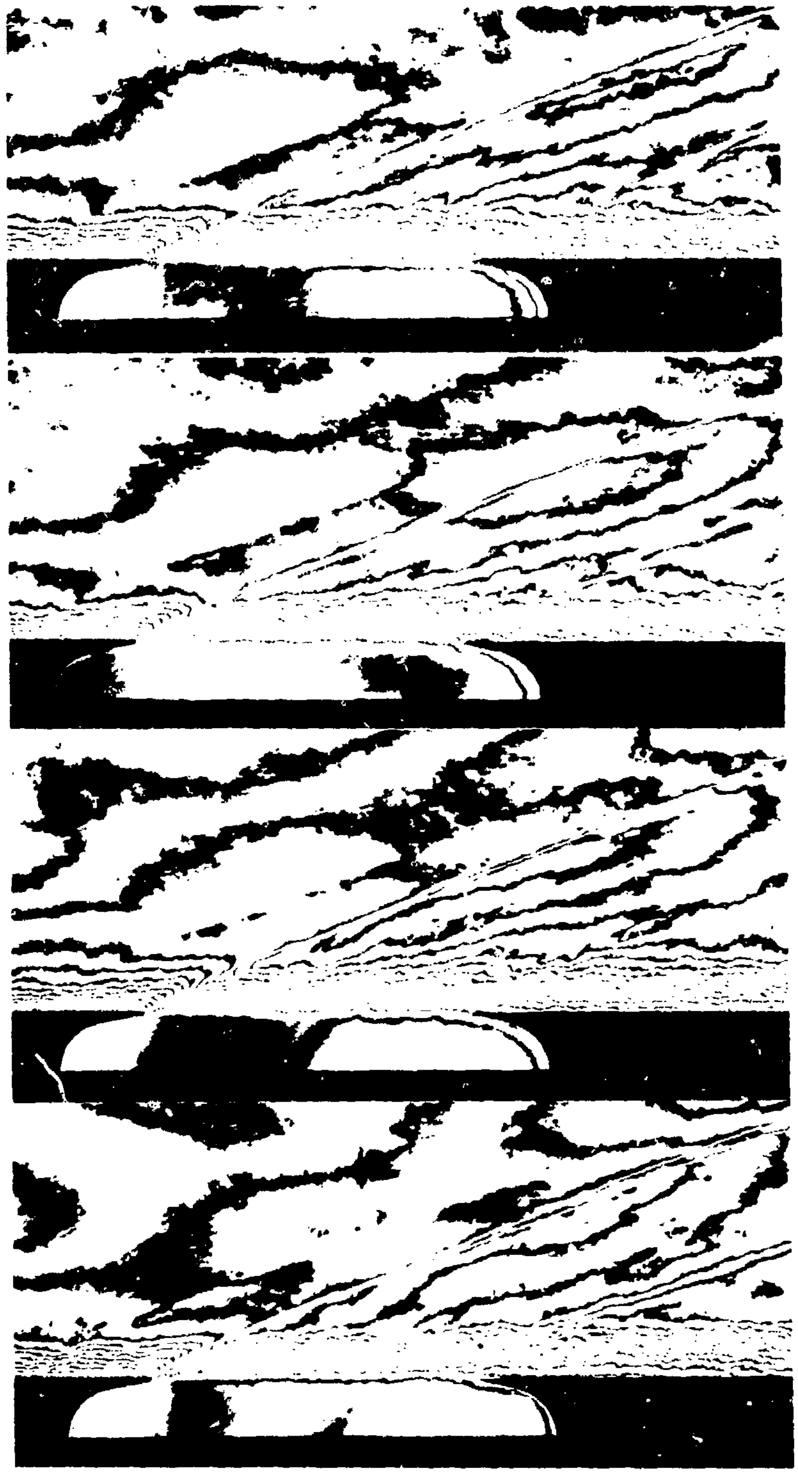


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Figure 8 EFFECT OF MASS INJECTION ON FLOW OVER CAVITY WITH SHORT OVERHANG LIP

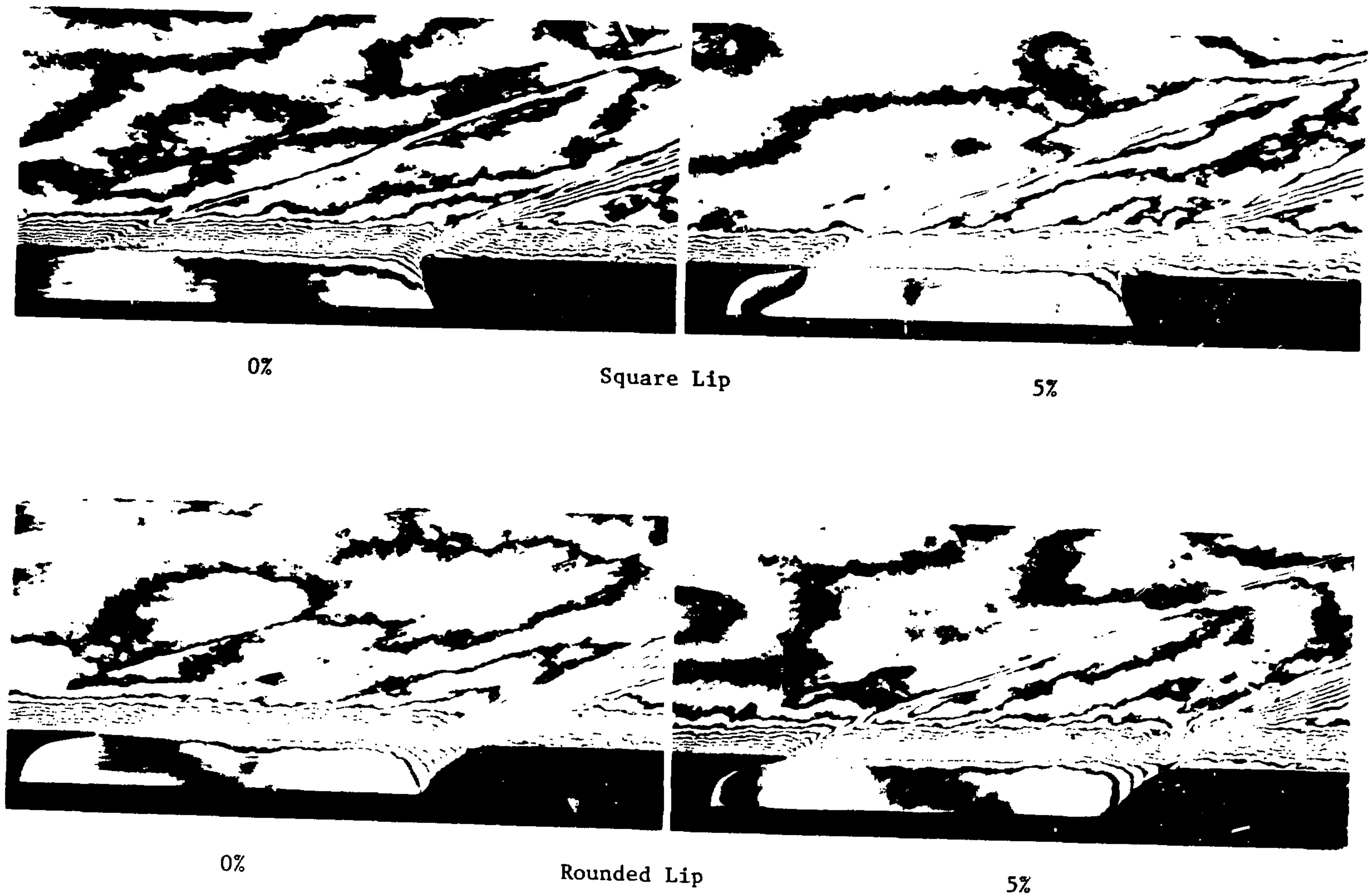

Figure 9 EFFECT OF MASS INJECTION ON FLOW OVER CAVITIES

REFERENCES

Ref 1: Korkegi, R. H., "Comparison of Shock-Induced Two- and Three Dimensional Incipient Turbulent Separation" to appear in AIAA Journal.

Ref 2: Smith, R. R., AF Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio, Private Communications, October 1974.

*Note: A more extensive report on cavity flows will be issued by ARL at a later date.

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